Before the
Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Office of Engineering and Technology Releases	)	ET Docket 13-26
and seeks Comment on OET-69 Software	)	
	)	
	)	
Expanding the Economic and Innovation	)	GN Docket No. 12-268
Opportunities of Spectrum Through Incentive	)	
Auctions	)	

REPLY COMMENTS OF SID SHUMATE, GIVENS & BELL, INC.

This reply is in response to the comments submitted by the National Association of Broadcasters

(NAB) and associated major television networks, on March 21, 2013, with regard to ET Docket 13-26 and

GN Docket No. 12-268.

First, I wish to commend the Office of Engineering and Technology for attempting, as directed by

Congress, to make improvements to the methodology of OET-69. As one who is familiar with the inner

workings of the NTIA's Irregular Terrain Model, (ITM), which resides as the core set of algorithms on

which the OET-69 operates, I recognize the significant effort this represents.

There are several claims and observations made by the NAB, on which I wish to provide comment.

1. The NAB notes that "OET Bulletin 69 and its software were an administratively accepted

methodology that had been applied in a predictable manner for many years". What is not noted

here is that the FCC has only reluctantly and relatively recently utilized the ITM-based algorithm set on which the OET-69 software is based, despite it being available since 1982. The FCC and Congress have long been "on the record" as having noted the significant shortcomings of this model, and Congress has long demanded improvement of this model throughout the series of legislation governing the reception of network television signals via commercial to-the-home Ku-band satellite delivery.

2. Congress's command is that the Commission "preserve, as of the date of the enactment of this Act, coverage area and population served". The NAB notes that "these values are generated only through the use of the OET-69 implementing software." What is not noted here is that the current OET-69 is not very good in determining the coverage area and population served.

To provide a baseline reference of how well (or badly) the ITM software works, I present the following. In 2010, I submitted a paper to the Fall IEEE Vehicular Technology Conference (VTC), held in Ottawa, Canada, promoting a replacement for the ITM. The paper was accepted as a poster presentation at the conference. In the poster presentation, (both attached as Appendix A to this reply), I analyzed the results of the FCC's own tests of the ILLM (OET-72) software results, as compared to a bank of 1069 measurements taken by the consulting firm of the late Jules Cohen. It should be noted that these measurements were all taken from television stations that were in the continental U.S., and east of the Mississippi river. It is also noteworthy that the OET-72 (ILLM) software utilizes the same core algorithm, the ITM, as OET-69, therefore the results are comparable. The graphical analysis shows the measurements, broken down into three ranges: line of sight, over a single obstruction, and over more than one obstruction.

In the line of sight range, the ILLM showed over-prediction of signal strength of an average of 10.3 dBu above the actual measured strength, with a Standard Deviation of 18.2 dBu. In the single obstruction area, the over-prediction drops to an average of 7.7 dBu, with a Standard Deviation of 10.8 dBu. And in what is often the critical area for interference determination and maximum range of coverage, the two or more obstruction range, the signal level is under-predicted, at –5.3 dBu (almost half the correct signal strength), with a Standard Deviation of 22 dBu. The diagrams on the right of the poster presentation show the error, the difference between the actual and predicted signal strength for each measurement in the range. The error diagrams are wide, and these results are from using the 30 arc-sec. terrain database for which the ITM is optimized.

This demonstrates a lot of room for improvement.   Therefore, the ITM and the prediction methodologies based on it, in OET-72 and OET-69, are, by comparison to professional TASO measurements, very poor predictors of signal strength, have essentially no positional accuracy, and cannot be relied on to accurately predict digital coverage area and population served.

3. In addition, as explained in a series of articles that I authored, published in the IEEE Broadcast Technology Society Newsletter, the ITM core algorithms respond by producing even worse results when used with better, more detailed terrain databases.

4. As to the validity of the results where the "error code" is noted, the averaging system in the ITM moves the measurement points when the "error" is indicated, compensating for the reason for the error code. The "error code" is but a minor warning that the compensation is being done. Therefore, the results at the "error code" points have been determined to be, in my informal tests, to no better or worse, on the average, than those at other nearby locations that do not exhibit the "error code".

The real problem here is with the ancient core ITM algorithm developed by the NTIA, who defends it against all comers. As an example, in the current Satellite reception legislation, set to expire soon, the provision requiring the use of the ITM core software did not exist in the language of the bills until after both the House and Senate had passed the bills. It was inserted by (now former) U. S Representative Rich Boucher, under "pressure from special interests", as a "Chairman's technical amendment" near the end of the bill's reconciliation session. It then received a perfunctory approval vote by both the House and Senate, and was signed by the President. It hardly represents "the will of the people".   The Spectrum Act simply followed the precedent set in the current Satellite legislation.

All of this puts the NAB is in the awkward position of having to defend the bad (the current OET-69), against the unintended consequences of well considered, rational improvements that don't work properly because the ITM core algorithm does not do what it claims to do, nor what is expected of it. What is needed is a major update of the ITM core algorithm, or a complete replacement based on more modern science.

Respectfully submitted,

Sidney E. Shumate
Givens & Bell, Inc.
1897 Ridge Rd.
Haymarket, VA 20169
(703)754-2478
sid@givensbell.com

APPENDIX A.

Longley-Rice and ITU-P.1546 Combined

A New International Terrain-Specific Propagation Model

Sidney E. Shumate

Givens & Bell, Inc.
Haymarket, Virginia, USA
tsunami@tidalwave.net

Abstract—A new propagation model and software implementation combines the best of the NTIA-ITS Longley-Rice methodology and it's Irregular Terrain Methodology (ITM) software implementation, a set of deterministic approximation equations derived from the empirical data in ITU-R P.1546 and other ITU Recommendations, and Snell's Law and Beer's Law, to create the first truly point-to-point, terrain-specific radio reception signal strength prediction model. This implementation utilizes 3-arc-second Satellite Radar Terrain data that is available internationally, making this a propagation model that can be implemented internationally. This new model more fully implements the original Longley-Rice Tech Note 101 methodology that does the ITM. The core software of this model, the equivalent of the ITM core, is the Irregular Terrain with Obstructions Model, the ITWOM. This model is specific and accurate enough to be used for the interference studies for which it was developed, has been in continuous development since 2005, and has been in use for two years by Givens & Bell to produce FM vehicular reception studies for analog and digital (IBOC) reception. Source code for a basic version of the ITWOM, designed for 3-arc-second database use and limited to the minimum range of the ITM and P.1546 recommendations, will be released.

Keywords- Longley-Rice, ITM, ITU Recommendations, ITU-R_P.1546, ITWOM, propagation prediction, radio, vehicular, mobile reception.

Introduction

Why do we need another new Longley-Rice implementation? Are there not dozens, perhaps hundreds, of Longley-Rice software packages in use? What is wrong with the 28-year old "benchmark", the U. S. Department of Commerce, National Telecommunications & Information Administration, Institute for Telecommunications Sciences (NTIA-ITS) Irregular Terrain Model (ITM) core software? Many engineers, over more than a decade, contributed to the creation of the ITS, and the NTIA-ITS defends it to this day, stating: "The ITM program has been carefully implemented and extensively tested, and NTIA is confident in recommending its use for transmission loss calculations."

The problem is that it does not work well, especially in the line-of-sight range and in the early diffraction range. These problems are in the ITM core software, and result, in part, from incompleteness of the NTIA's original Longley-Rice Technical Note 101 [1] (TN101) methodology. As a result, we find in the NTIA-ITS 2008 annual progress report that "ITS was tasked by NTIA/OSM to review and evaluate the current propagation models and ITU-R Recommendations to determine which could be used to perform propagation analyses to facilitate EMC analyses of mobile wireless devices[1]. After performing an exhaustive review of current models, ITS determined that none was entirely suitable for use in analyzing mobile-to-mobile (MTOM) interference interactions."

Dr. Oded Bendov noted in his 1998 paper that, when comparing field measurements taken in 1994 during the Grand Alliance's HDTV transmission subsystem tests to both a Longley-Rice map and to a simple radio horizon map, "the radio horizon map provided a more realistic prediction of coverage than the LR model[1]."

The Federal Communications Commission, in the U.S., adopted the Longley-Rice ITM as the core software in its Longley-Rice DTV coverage and reception analysis implementations over a decade ago, but has twice tried unsuccessfully to improve the implementation using the existing ITM core, and has once again been ordered, in legislation enacted on May 27, 2010, to improve its Longley-Rice DTV reception implementation within 270 days[4].

Givens & Bell started out trusting the ITM model to be a true point-to-point model, and, it having been in use for more than two decades, expected it to be well perfected. But we found when performing testing and analysis of the ITM model utilized as an all-terrain-points interference model, calculating for all terrain points in a 170 km radius, for over a thousand FM radio stations in the Washington, D.C. test market, in order to predict not only signal strength but also D/U co- and adjacent interference ratios for all stations in the test market, that the model worked poorly, especially at predicting reception at specific, individual terrain database points, and that performance declined as the terrain database increased in detail from 30-arc-second to 3-arc-second intervals. Therefore, we found it necessary to analyze, correct, complete, and update the ITM to be a true point-to-point, terrain-specific model. After sufficient internal testing, further development, and use, we have decided to release a basic version of this new implementation as a c++ source code set, an ITM drop-in replacement, to allow international use and testing of this model.

Why Does the ITM Point-to-Point Mode Work So Poorly ?

Visualize a Longley-Rice software implementation as being like a jelly doughnut. Think of the jelly as the unchanging, 'Irregular Terrain Model" (ITM) set of software subroutines finalized in 1982, the "core". The surrounding baked dough represents the many wrap-around input-output software surround packages,

including dozens of proprietary and open-source versions by commercial firms and by government agencies. More detailed terrain data has not provided better results, and the reasons why are in the core:

1. The core software works best with terrain databases with no more than 30 arc-second detail. Most users today attempt to use more recent and more detailed 3-arc-second, 1-arc-second, or 1/10-arc-second databases. Because of limitations in the software regarding the calculation of the terrain irregularity factor, delta h, and because of the radial averaging system, the use of a more detailed terrain database does not significantly improve the results.

2. The ITM core does not implement many of the features in NTIA Technical Note 101 (TN101), the landmark work on which it is supposedly based. This includes the important omission that it does not actually consider single, individual terrain obstructions, except for distant, earth-curvature horizons at the end of mildly irregular terrain (from which comes the "Irregular Terrain" name). It also does not compute for more than two obstructions in a radial path.

3. Because the single-obstruction knife-edge diffraction calculations in the original Longley-Rice TN101 methodology are the same as those found in ITU-R P.526-6 Section 4.1, the results are not valid when a grazing angle exceeds 12 degrees, i.e. when either the transmitter or receiver are too close to the obstruction. Since the ITM has to compute losses as the receiver antenna site moves along a radial, approaching, passing over, and moving beyond the peak of knife edge obstructions, the ITM has a radial averaging system that averages all answers based on calculation of a few selected terrain points leading up to, and following, the actual terrain point location being evaluated. These points are selected on the basis that the ITM can calculate at those points on a radial. Therefore, the ITM cannot provide true point-to-point, terrain-point-specific answers, it can only provide point-to-averaged-terrain-points-along-a-radial answers.

4. TN101 does not explain where the third source of signal loss comes from in the line-of-sight range. Two are accounted for, the Free Space Loss, and the Two-Ray Multipath Loss. The ITM, which was required to provide an answer, estimates "diffraction" loss in the line-of-sight range based primarily on the estimated diffraction loss well past the horizon, calibrated against empirical test results. This loss can now be accurately and scientifically determined from a combination of Snell's Law, Beer's Law, and Radiative Transfer Engine (RTE) Clutter loss, but the ITM has not been updated.

5. As a result, the ITM core cannot do what it says it does. The "point-to-point" subroutine, apparently a late addition, reports that single obstructions are being considered, but in fact many of the older, actual working software algorithms found in DIFF, SCAT and LOS in a previous 1968 work, are still found actually doing the work today, rewritten into subroutines adiff, ascat, alos and lrprop, and they do not directly consider individual obstructions. Obstructions are not directly considered until at or after the horizon, and then only as a specific pair: the highest obstruction "visible" from the transmitter antenna, and the highest obstruction "visible" from the receive antenna.

6. In addition, the ITM core has several math errors and outdated approximations. The NTIA-ITS staff adamantly backs the ITM "as is", rebuffing any attempt to point out the errors, and refusing any offer of suggested fixes.

For these reasons, to achieve the objective of true "point-to-point", terrain-specific Longley Rice predictions, it was necessary to create our own corrected, completed, and updated ITM-equivalent core. Only minor adjustments need to be made to existing wrap-around "doughnuts" to accommodate the basic improvements in the new ITWOM core.

Correcting the ITM

First it was necessary to study, analyze, and, as we found, make corrections to the existing ITM core before completing and updating the methodology. The housekeeping corrections that had to be made were published in detail in a series of articles published in the IEEE Broadcast Technology Society (BTS) Newsletter since Fall, 2007; the description of the corrections start with the Spring 2009 article. The articles also provide more detail on other poorly documented and undocumented parts of the ITM algorithm. Since this paper primarily deals with the completion and updating of the ITM into the ITWOM, here I will only summarize the corrections made. Note that all of these apply to both the current FORTRAN and c++ versions of the ITM. The housekeeping corrections included:

The Linear Least-Squares algorithm in subroutine *z1sql* is corrected to fix a problem with the calculation of the terrain irregularity parameter delta-h. (Spring 2009 article).

The *dlthx* subroutine is updated, in two places, to allow the proper calculation of delta-h based on the interval size of the terrain databases for intervals shorter than those of 30-arc-second databases (Fall 2009 article).

An application of a complex conjugate, resulting in a miscreant minus sign, is no longer appropriate after a change in the derivation of the reflectivity coefficient of a reflected ray is implemented. The minus sign is removed from subroutine *alos*. (Winter, Spring, Summer and Fall 2009 articles).

The use of effective heights for the transmitter and receiver antenna heights, and of a calculated average terrain height for two-ray reflection point height and for other purposes, is replaced by actual heights, taken from the terrain database.

Completing the ITM

The losses calculated in the line-of-sight range are from three sources. TN101 discusses Free Space Loss and Two Ray Loss calculations in the line of sight range.

The two-ray multipath calculation determines the field strength of a signal at a receive location, as a signal reflected off of the ground combines with the direct signal. This reflected signal can theoretically combine with the direct signal, to create up to a 6 dB peak (in RF voltage, the measure of field strength) or a perfect null. In practical use, the peak is rarely seen to be more than 3 dB, and the null rarely exceeds 20 dB, even under ideal, smooth bare earth conditions. The full effect of this multipath would be to create a "comb filter" like series of narrow, deep nulls in the signal path as the distance increases, with each subsequent null further apart than the last. At low reflection angles, there is a phase reversal at the reflection point, so when the two signals become less than one-half wavelength apart, the two signals increasingly cancel as the path distance increases, fading toward a null point beyond the horizon. The Irregular Terrain Model eliminates the narrow nulls before the one-half wavelength point, and uses only the slowly increasing null from the last, long, slow fade. But this only functions well over smooth, hard earth. When dealing with ground with clutter cover and/or irregular terrain, the reflected signal path passes through the foliage clutter layer twice (once to reach the ground, then from the ground toward the receiver) quickly absorbing the reflected ray, eliminating the multipath effect entirely for the first 15 to 30 km. or so, out to where the reflectivity of the clutter canopy, R_{CH}, approaches unity, and the reflected ray sees the clutter canopy, and/or the rough terrain at a low reflection angle, as a good reflector, a phenomenon documented by Donald Barrick[5]. Since we do now use highly detailed terrain path databases that support accurate placement of the nulls, the new ITWOM has been changed to include the earlier "comb filter" Fresnel-zone nulls generated by the two-ray calculations.

The early path two-ray multipath losses are attenuated by ground clutter when the terrain roughness factor, delta-h exceeds a value of 4; and Longley-Rice states that the U. S. average terrain roughness factor is delta-h = 90. Which pretty much leaves only the free space loss for most of the average line-of-sight path. But field test results, and the ITU-R P.1546 empirical data curves, show losses in the line-of-sight path that are far greater than just the free space dispersion and two-ray loss combined.

TN101 does not address the cause. A. G. Longley and P. L. Rice, in creating the pre-ITM computer code found in ITS-67, were apparently at a loss to explain what caused this attenuation, and substituted a calculation of average diffraction losses, calculated at locations past the horizon, to solve for a straight-line formula (Attenuation = a*distance +b), and then used the answer from this formula, solved at the path distance being considered, as the value of the unexplained attenuation in the line-of-sight range. Whatever slight validity this method has, disappears entirely when consideration of obstructions are added, yet this early substitute is still in use. Dr. Harry Anderson, of EDX, describes this empirical substitute and objects to its continued use in his 2003 book[5]. To replace this forty-year old temporary methodology, we needed to know what is causing the attenuation, and how to calculate it. The obvious answer is that the clutter and terrain irregularities are causing it. But if we attempt to look at this as direct clutter absorption, referencing the equations in ITU-R P. 833-2 (P.833-2), we get far too much attenuation. A study of the empirical data charts 1, 9, and 17 of the International Telecommunications Union (ITU) Recommendation P.1546-2 "Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3000 MHz" (P.1546-2), shows that for short ranges up to 50 meters, the average attenuation from direct absorption in average clutter is approximately 0.02 dB/meter. Imagine the effect of a forest, and the attenuation received in a direct radio path where a transmitted signal would pass through a mile or so of trees and other clutter near the horizon to get to an FM radio antenna on a vehicle. So how does the signal even get to a car driving through a forest?

It gets there by way of a phenomenon known as Radiative Transfer. Radiative Transfer refers to several combined phenomena that describe the near-lossless scattering and reflecting, millions of times, of a radio signal under (ground reflection), over, and around vegetation and man-made clutter. This takes about 50 meters of distance to start to function, as shown by the rising straight line in Figure 1 of P.833-2, so the first 50 meters are referred to as the first term, or I_{ri} mode, and can be described by a simple, straight line Beer's Law absorption function, $A = AB*$radio path distance, where, at its simplest, the AB term is a straight line formula, and the cluttered radio path distance is the theoretical actual central path taken by the radio signal through the clutter.

From a study of the data in P.1546-2, we find that the second stage of Radiative Transfer, (the total of which is known as the Radiative Transfer Engine, or RTE) the second term, also identified by Qinetiq as part 1 (I_1) of the ID (scatter phenomenon) a simple scatter phenomenon, only lasts for 10 to 15 meters, starting at about 50 meters into the woods, and can, for most practical purposes, be ignored, or computed as the early part of the I_2 function curve.

The next stage, the second term, I_2 of I_d, an incoherent scatter function term, takes priority in determining the attenuation at about 60 to 65 meters into the woods. For a case where both the transmitter and receiver are at or below the clutter "canopy top", this mode continues for a few hundred meters, until the increasing signal phase scattering makes the I_d mode signal unrecoverable.

Recommendation P.1546, as stated in P.1546-1, Annex 5, Section 3, is not valid when the transmitting/base antenna is below the surrounding clutter canopy height. This restriction then transfers to the new ITWOM, as the clutter calculations are derived from P.1546-2 curves. These equations, and their derivation, was described in a paper (ISART paper) presented before the NIST-ITS 10th annual International Symposium on Advanced Radio Technologies (ISART) in Boulder, CO, in June of 2008[7]. Please refer to this paper for the deterministic approximation equations and application notes.

P1546-1, Annex 5, Section 9, discusses the height of the ground cover surrounding the receiving/mobile antenna, which is subject to a minimum height value of 10 meters, and gives examples of reference heights of 30 meters for a dense urban area, 20 meters for an urban area, and 10 meters for a suburban area. The average effective clutter canopy top height in the P.1546-2 data curves, was derived in the ISART paper, to be 25.2 meters, using an iterative solution of the I_{ri} term.

A fourth stage of RTE, I_3, only appears when the transmitter is above the canopy top, and the receiver is at or under the canopy top. Here, an approximately equally weighted combination of a fading RTE mode, and a Beer's Law absorption mode, provides the lowest-loss path for the signal, up to and just past the horizon or tallest obstacle visible from the transmitter site, where diffraction mode takes over. This stage starts when the canopy top distance above the radio path reaches about 225 meters in length.

Why does the RTE function not run out its course as the direct signal, passing below the clutter canopy in a straight line modified only by the 4/3 earth atmospheric diffraction correction factor, passes below the clutter canopy and travels for hundreds or thousands of kilometers to reach a vehicular-mounted antenna? The most interesting part of this new calculation is that it was found by analyzing the P-1546-2 curves, that when the transmitter is above the clutter canopy, and the receiver is below the clutter canopy, the central path of the radio signal wavefront does not just gently bend due to atmospheric diffraction, but it also splits when it comes in contact with the clutter canopy, with part of the signal reflecting off of the top of the clutter canopy, and a second part of the signal taking a path with a sharp downward bend into the clutter, as per Snell's Law. This significantly changes and shortens the signal path through the clutter below the canopy, in the same way that an almost-horizontal flashlight beam aimed slightly down into the water in a rectangular fish tank does not land on the far wall, but bends down and lands on the bottom of the fish tank.

The new equations for the clutter loss functions derived from P.1546 have been applied to the line of sight range in the Longley-Rice ITWOM implementation in multiple scenarios, with the clutter loss function losses added to the free space loss and two-ray loss in the line of sight range, which now extends across the line of sight and up the side of the first obstruction, switching to a single-point diffraction loss calculation at the top of an isolated obstruction. Past the peak of an isolated obstruction the signal diffracted across the obstruction is treated as a secondary transmission source, and the loss down the far side of the obstruction are calculated using the free space loss and clutter loss calculations out to where the grazing angle from the receiver to the obstruction is less than eleven degrees. At this point the original TN101 methodology for a single isolated obstruction is implemented and followed, with the addition of the clutter loss calculations if appropriate, up to where the moving receive site reaches the top of a second obstruction not observable from the transmitter site. When this occurs, the TN101 methodology for two

obstructions, as originally implemented in the ITM, takes over momentarily at the top of the second obstruction. As the receive site then moves past the top of the second obstruction, the signal diffracting over the second obstruction is treated as a transmission source, and the free space loss and the clutter calculations are used down the far face of the second obstruction, again switching to the original TN101 methodology when the grazing angle from the receive site to the top of the second obstruction becomes less than eleven degrees. The averaging system is removed for the line of sight and diffraction range calculations. The original TN101 tropospheric scatter (troposcatter) methodology, as implemented in the ITM, is changed only in that the switch point between diffraction and troposcatter ranges is determined as per TN 101, not as in the ITM.

The averaging system, which exists only in the ITM and not in the TN101 methodology, is removed for the line-of-sight and diffraction ranges. The use of fed-back diffraction losses in the line of sight range has been replaced by the new clutter loss equations and methodology. The result is a terrain-specific calculation of the predicted signal strength loss, the first true point-to-point implementation, which has required using the best of the Longley Rice TN101 methodology, completed with equations derived from multiple ITU-R recommendations, primarily from ITU-R P.1546, and including ITU-R P.453, P.530, and P.833.

Limitations of the ITM Retained

In order to provide for drop-in compatibility, and direct comparisons between the old ITM and the new ITWOM source code cores, certain characteristic limitations of the classic ITM core have been retained for now.

The ITWOM basic source code does not include computations for over-water propagation, as found in the proprietary TIREM model, which also has its roots in the ITS-67 FORTRAN source code and TN101 methodology.

The ITWOM basic source code also still retains height- distance path length approximations that start to fail near the transmitter site, instead of using a more rigorous Pythagorean computation that would be valid all the way to the antenna near-field.

The current error code reporting system is retained.

New input parameters are coded at present values, including the clutter density coefficient (which could be adjusted based on Land Use data) preconfigured for a value of unity (1.0), and not coded to be variable by the surrounding input-output software.

The computation of the free-space-loss path distance does not include the height difference compensation mentioned in the ISART paper, and in a paper published in China[8]. This affects the accuracy of computations near most broadcast transmitter sites, and anywhere the vertical distance between the transmit antenna and the receive antenna is significant.

Comparison of Results

The following graphics show the visible difference in detail between the use of the original ITM, in the top image, and the new ITWOM core software in the bottom image.
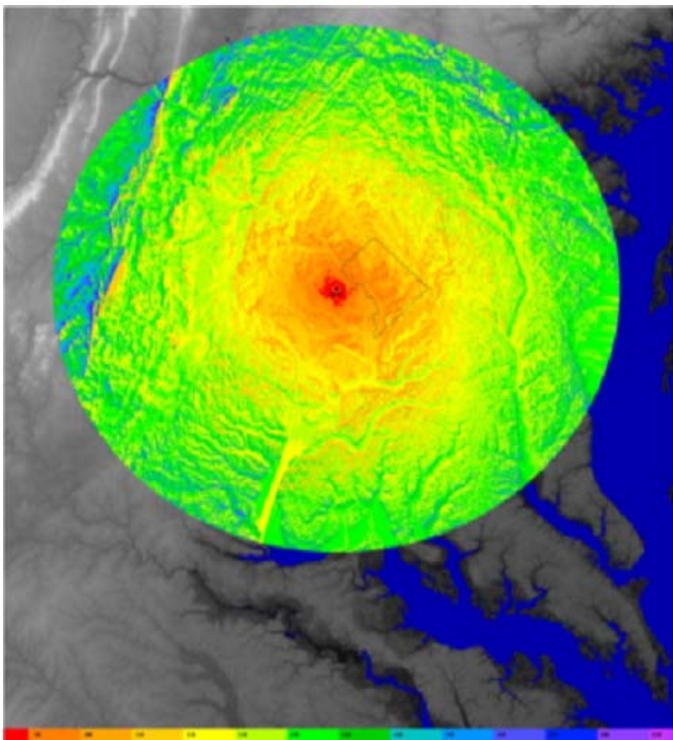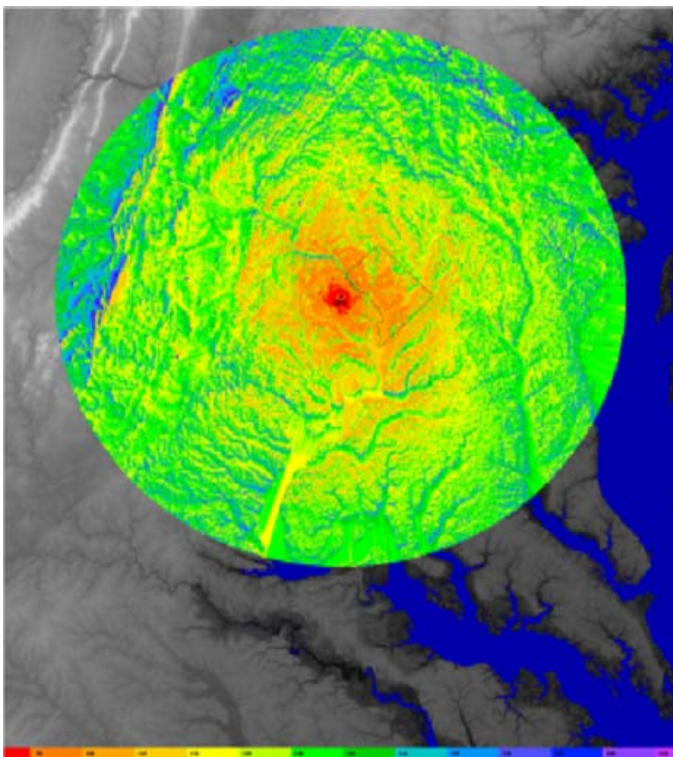
Fig. 1, ITM Example.

Fig. 2, ITWOM Example.

Future Development

The issues raised in the retained limitations section above will be addressed in the Professional International version, which will be released as a fully developed software package that includes improvements beyond the scope of TN101 and the ITM.

Summary

The release of the ITWOM basic source code provides to the users in the U.S., and world-wide users of the Longley-Rice prediction methodology, a corrected, completed and updated new set of core Longley-Rice subroutines, the ITWOM, a drop-in replacement for the ITM core.

To those that are used to using ITU-R Recommendations, it is a long-awaited, terrain-and-obstruction-adjusted computer source code implementation of the ITU-R Recommendations. It can be immediately implemented for use with the worldwide Shuttle Mission Satellite Radar 3-arc-second data that is available for download at no cost via the Internet from the U.S. government.

REFERENCES

[1] P.L. Rice, A.G. Longley, K.A. Norton, and A. P. Barsis. "Transmission loss predictions for tropospheric communications circuits", Technical Note 101, revised 1/1/1967, U.S. Dept. of Commerce National Telecommunications & Information Administration, Institute for Telecommunications Sciences (NTIA-ITS).

[2] NTIA-ITS "2008 Annual Progress Report", section on "Telecommunications Engineering, Analysis and Modelling", subsection on "Short Range Mobile to Mobile Propagation Model Development and Measurements", page 48-49.

[3] Dr. Oded Bendov, "On the validity of the Longley-Rice (50,90/10) propagation model for HDTV coverage and interference analysis". 1998. Dielectric Corp., Raymond ME, USA.

[4] S.3333, Satellite Television Extension and Localism Act of 2010 (STELA), signed into law May 27, 2010. Section 204(b)(3), "Establishment of improved predictive model and on-location testing required-(A) Predictive model". U.S. Congress, Washington, D.C.

[5] Donald Barrick, "Grazing behavior of scatter and propagation above any rough surface" IEEE Trans. On Antennas & Propagation, Jan. 1998.

[6] Dr. Harry R. Anderson, "Fixed Broadband Wireless System Design", Wiley Interscience, April 2003.

[7] Sidney E. Shumate, "Deterministic equations for computer approximation of ITU-R P.1546-2", presented before the 10th annual International Symposium on Advanced Radio Technologies, Boulder CO, June, 2008. Givens & Bell, Inc., Haymarket, VA. USA.

[8] Wang Zuliang, Zheng Mao, and Zheng Lihjua of the College of Electrical Science and Engineering, National University of Defense Technology, Changsha 410073, P.R. China, and Wang Juan, Beijing Institute of Tracking and Telecommunications Technology, Beijing, 100094, P.R. China. "Improved algorithm of atmospheric refraction error in Longley-Rice channel model". Journal of Systems Engineering and Electronics, Vol. 19, Issue 4, Aug. 2008, pages 683-687.

Abstract—A new propagation model and software implementation combines the best of the NTIA-ITS Longley-Rice methodology and it's Irregular Terrain Methodology (ITM) software implementation, a set of deterministic approximation equations derived from the empirical data in ITU-R P.1546 and other ITU Recommendations, and Snell's Law and Beer's Law, to create the first truly point-to-point, terrain-specific international radio reception signal strength prediction model. This implementation utilizes 3-arc-second Satellite Radar Terrain data that is available internationally, making this a propagation model that can be implemented internationally. This new model more fully implements the original Longley-Rice Tech Note 101 methodology that does the ITM. The core software of this model, the equivalent of the ITM core, is the Irregular Terrain with Obstructions Model, the ITWOM. This model is specific and accurate enough to be used for the interference studies for which it was developed, has been in continuous development since 2005, and has been in use for two years by Givens & Bell to produce FM vehicular reception studies for analog and digital (IBOC) reception. Source code for a basic version of the ITWOM, designed for 3-arc-second database use and limited to the minimum range of the ITM and P.1546 recommendations, will be released.

WHY UPDATE THE NTIA-ITS IRREGULAR TERRAIN MODEL (ITM)?

1. The core software works best with terrain databases with no more than 30 arc-second detail. Because of limitations in the software and the radial averaging system, the use of a more detailed terrain database does not significantly improve the results.

2. The ITM core does not implement many of the features in NTIA Technical Note 101 (TN101), including that it does not actually consider single, individual terrain obstructions.

3. The single-obstruction knife-edge diffraction calculations in the original Longley-Rice TN101 methodology are not valid when a grazing angle exceeds 12 degrees, close to an obstruction. The ITM compensates with a radial averaging system. Therefore, the ITM cannot provide true point-to-point, terrain-specific results, only point-to-averaged-terrain-points-along-a-radial results.

4. TN101 does not explain where the third source of signal loss comes from in the line-of-sight range. The ITM uses an empirical "patch", incorporated in the averaging system, to compensate. This unexplained loss can now be scientifically determined from a combination of Snell's Law, Beer's Law, and Radiative Transfer Engine (RTE) Clutter loss.

5. The ITM core cannot do what it says it does, in the point-to-point mode. Obstructions are not directly considered until at or after the horizon, and then only as a specific pair: the highest obstruction "visible" from the transmitter antenna, and the highest obstruction "visible" from the receive antenna.

6. In addition, the ITM core has several math errors and uses poor approximations instead of more accurate geometric calculations. The NTIA-ITS staff adamantly backs the ITM "as is", rebuffing any attempt to point out the errors, and rebutting any corrections or updates offered for their 25 year old reference benchmark software.

ITM (1985) as ILLR (2005)

## Results of FCC ILLR model tests from 2004, comparison to 1069 field measurements.

ILLR results are NTIA-ITS ITM core results with additional attenuation for clutter loss based on Land Use as per OET Bulletin OET-72. Used for the most fair comparison to ITS results, as ITWOM includes average clutter loss determined from ITU-R P.1546 data.
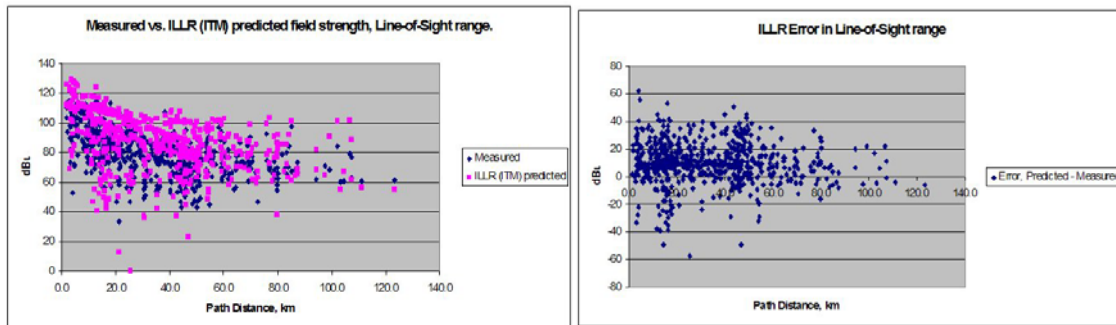
ILLR (ITM) in Line of Sight Range:
Average Error: 10.3 dBu (Predicting above Measured),
Variance 330.1 dBu, Standard Deviation 18.2 dBu
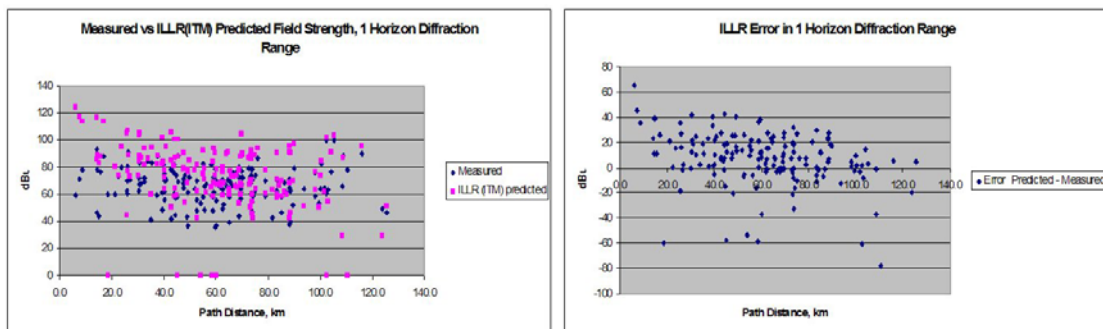
ILLR (ITM) in Single Horizon or Obstruction Range:
Average Error: 7.7 dBu (Predicting above Measured),
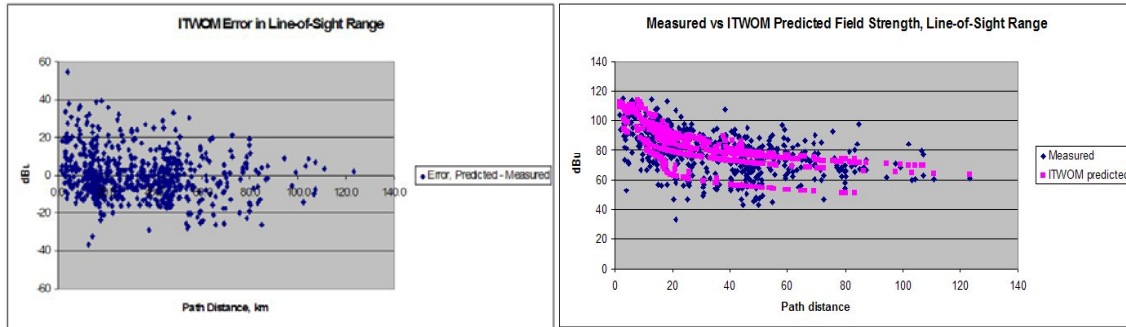Variance 117.3 dBu, Standard Deviation 10.8 dBu
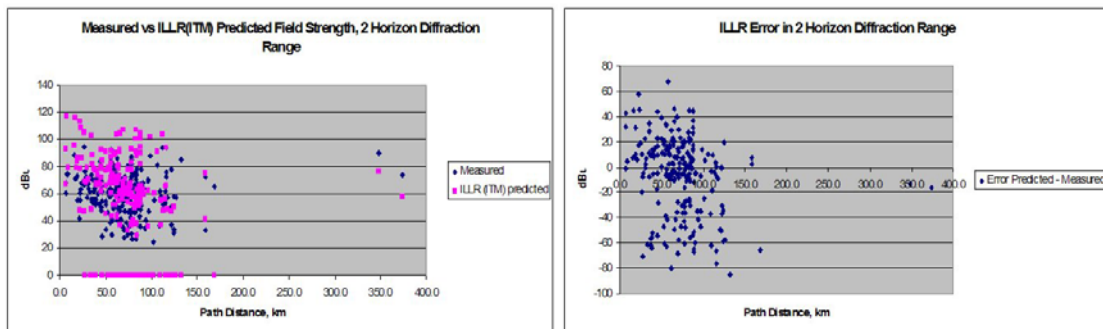
ILLR (ITM) in Separate Horizons or Two Obstruction Range:
Average Error: -5.3 dBu (Predicting below Measured),
Variance 312.4 dBu, Standard Deviation 17.7 dBu

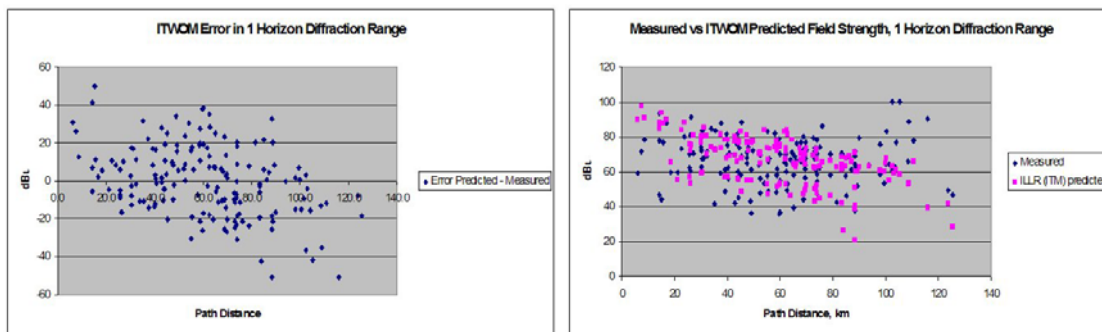Full Set: Ave. Error 6.6 dBu; Variance 482 dBu; Std. Dev. 22 dBu

ITWOM – 2010

## Compared against 1069 field measurement results from FCC 2004 ILLR model tests.

ITWOM results are set for 22.5 meter clutter height to match average ILLR clutter results; use 25.2 meter clutter height for ITU-R P.1546 calibration (international use). Foliage-top scatter calibrated against FCC measurements. 3-arc-second SRTM3v2 data.

ITWOM in Line of Sight Range:
Average Error: 0.09 dBu,Variance 142.1 dBu,
Standard Deviation 11.9 dBu.

ITWOM in Line of Sight Range:
Average Error: 0.01 dBu, Variance 82.5 dBu,
Standard Deviation 9.1 dBu.
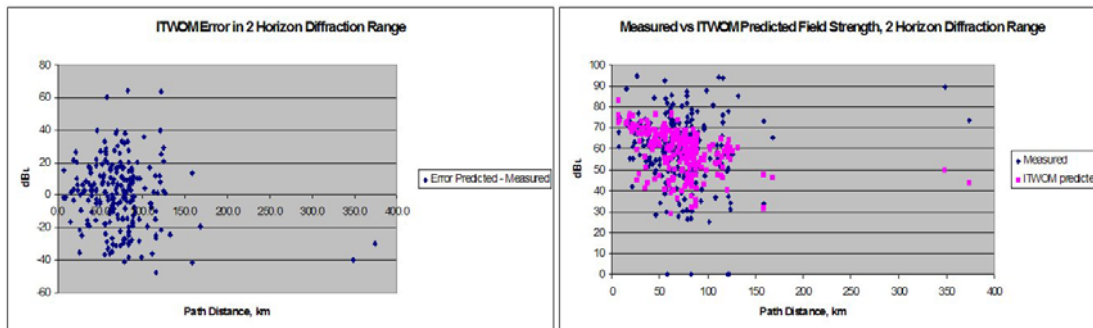
ITWOM in Separate Horizons or Two Obstruction Range:
Average Error: 0.013 dBu, Variance 140.0 dBu,
Standard Deviation 11.8 dBu.

Full Set: Ave. Error 0.1 dBu; Variance 229.3 dBu; Std. Dev. 15.1 dBu

CREATING THE ITWOM
(IRREGULAR TERRAIN WITH OBSTRUCTIONS MODEL)

1. Corrections were made to subroutines z1sq1 and dlthx to remove the terrain database detail size limits and improve the calculation of the terrain irregularity parameter.

2. Corrections were made to subroutines alos, adiff, and lrprop to correct math errors in computing the two-ray losses and knife-edge diffraction losses.

3. The use of effective height is being phased out, replaced by actual height of two-way reflected point height and actual transmitter and receiver heights, and the true transmitter antenna to receive antenna distance, instead of the path distance, is now used when calculating free space loss.

4. The empirical "diffraction loss in the line-of-sight range" calculation, and the associated radial averaging system, have been removed, replaced by clutter loss calculations utilizing Snell's Law, Beer's Law, and Radiative Transfer Engine Clutter Loss calculations, to calculate clutter loss in the line-of-sight range and behind obstacles. These new deterministic clutter loss approximations were derived from, and calibrated against, the data from ITU-R P.1546, and are known as "Shumate's approximations".

5. Addition of foliage scatter factors to compensate for moderation of knife-edge diffraction loss over foliage-topped obstacles.

6. Two-ray calculations now report out early path comb-filter "Fresnel Zone" effects previously suppressed in the ITM.

7. The basic software core used in the tests was written as a "dual core" software set, and incorporates both the ITM and ITWOM sets of software to allow testing and comparison of the results, using the same "wrap around" software core.

8. The software has been tested, calibrated for U.S. use, and compared using the 1069 VHF and UHF measurements from the ILLR test set used by the U.S. Federal Communications Commission (FCC) to calibrate and test the ILLR model (which relies on the ITM core software), in 2004-5.

> The U.S. Congress has ordered the FCC to improve its ILLR model by late November of 2010. This ITWOM dual core model is Givens & Bell's bid to replace or supplement the current ITM core, and has been offered to the FCC in current proceedings as comment in OET 10-156 and as a petition for further rulemaking in proceeding OET 00-11. A c++ language copy of the source code, with installation instructions and more test details, is available from the author on request, including at this presentation.